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(58) Field of search **C3V H4J**

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(54) **Diaphragm for loudspeaker**

(57) A diaphragm for a loudspeaker comprising a cured molding of a rubber.

FIG. 1

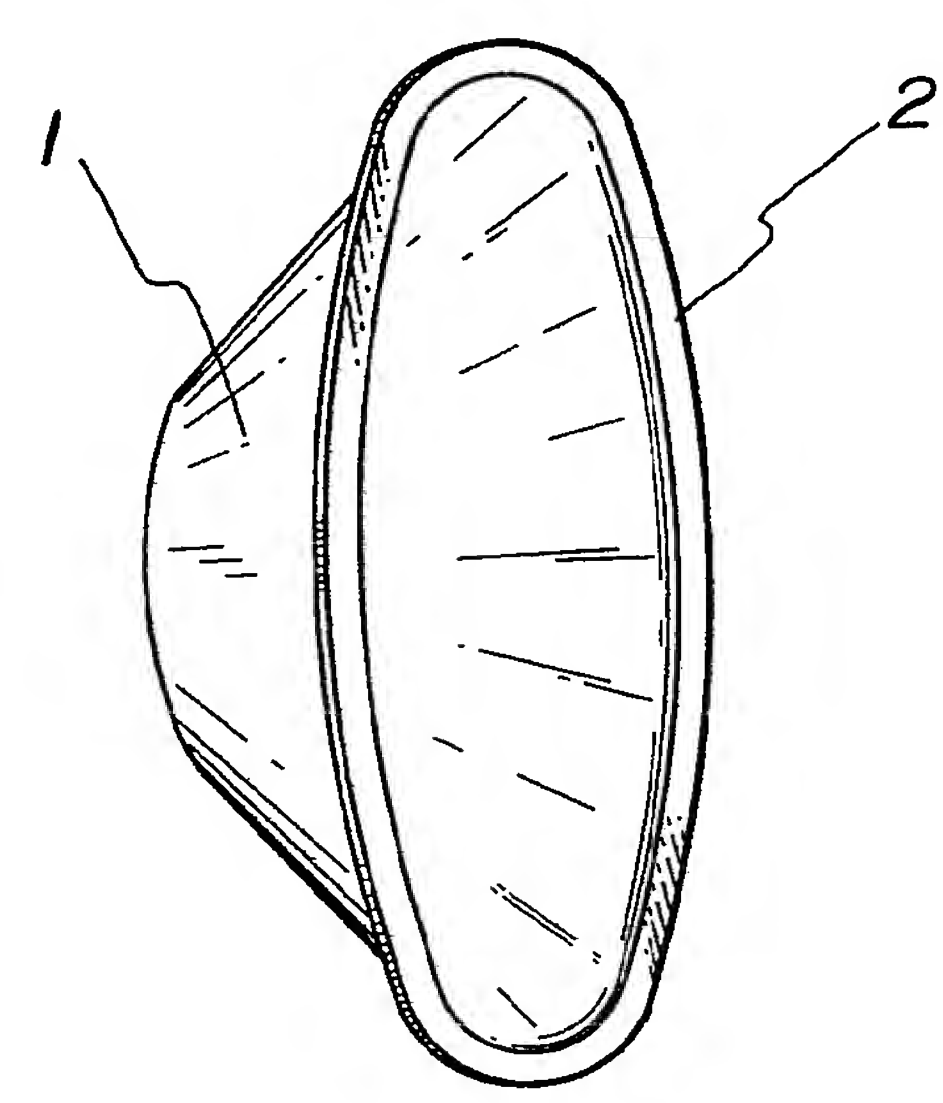

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FIG. 1

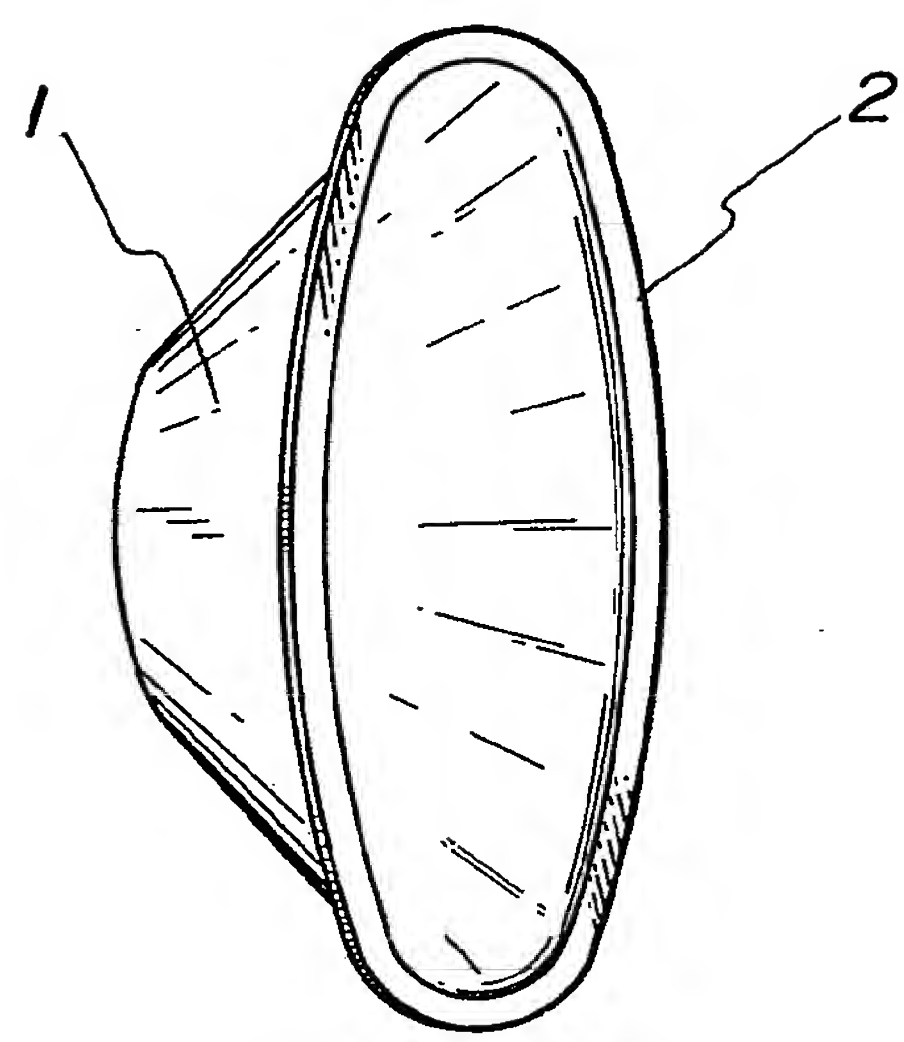

FIG. 2

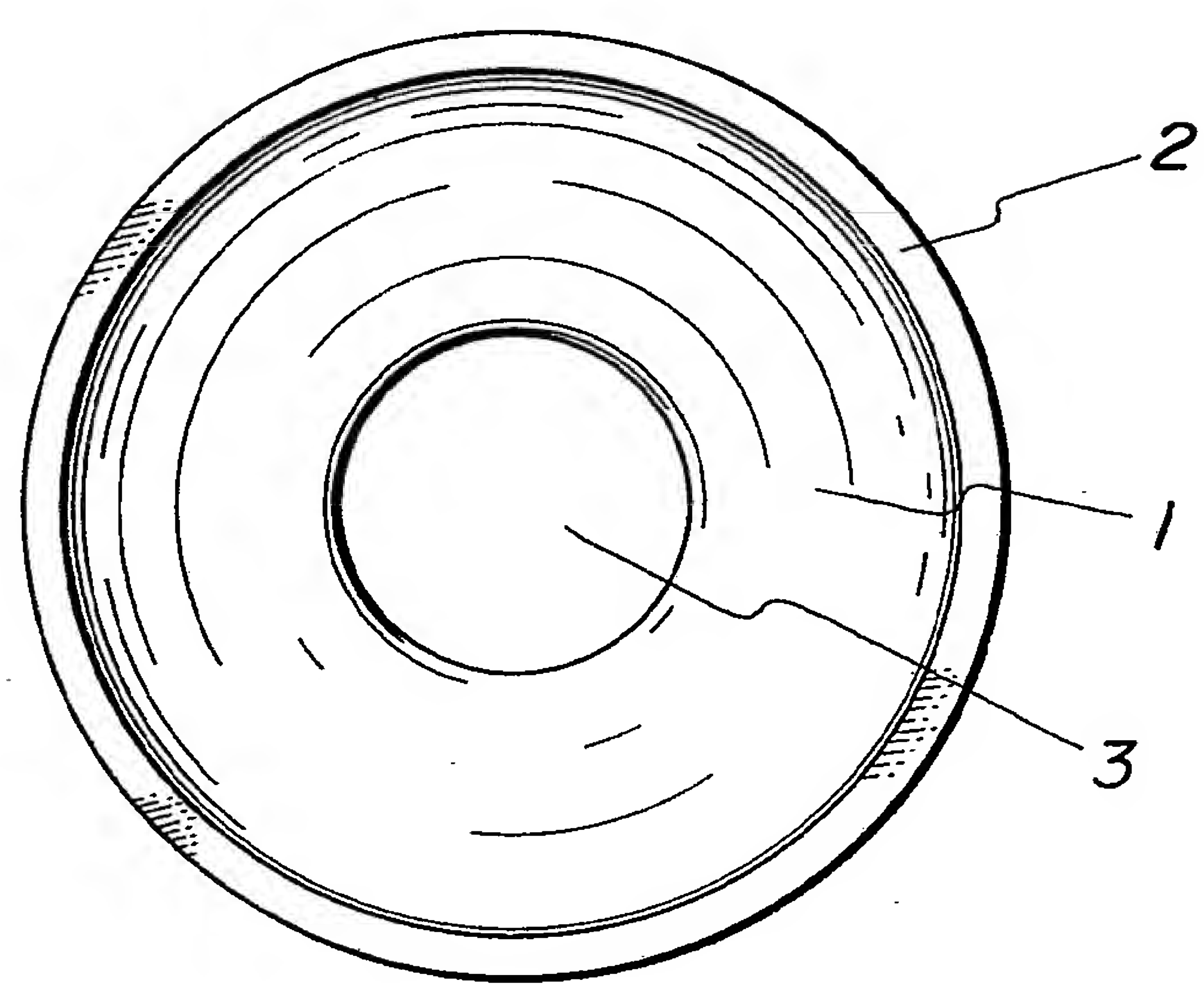

FIG. 3

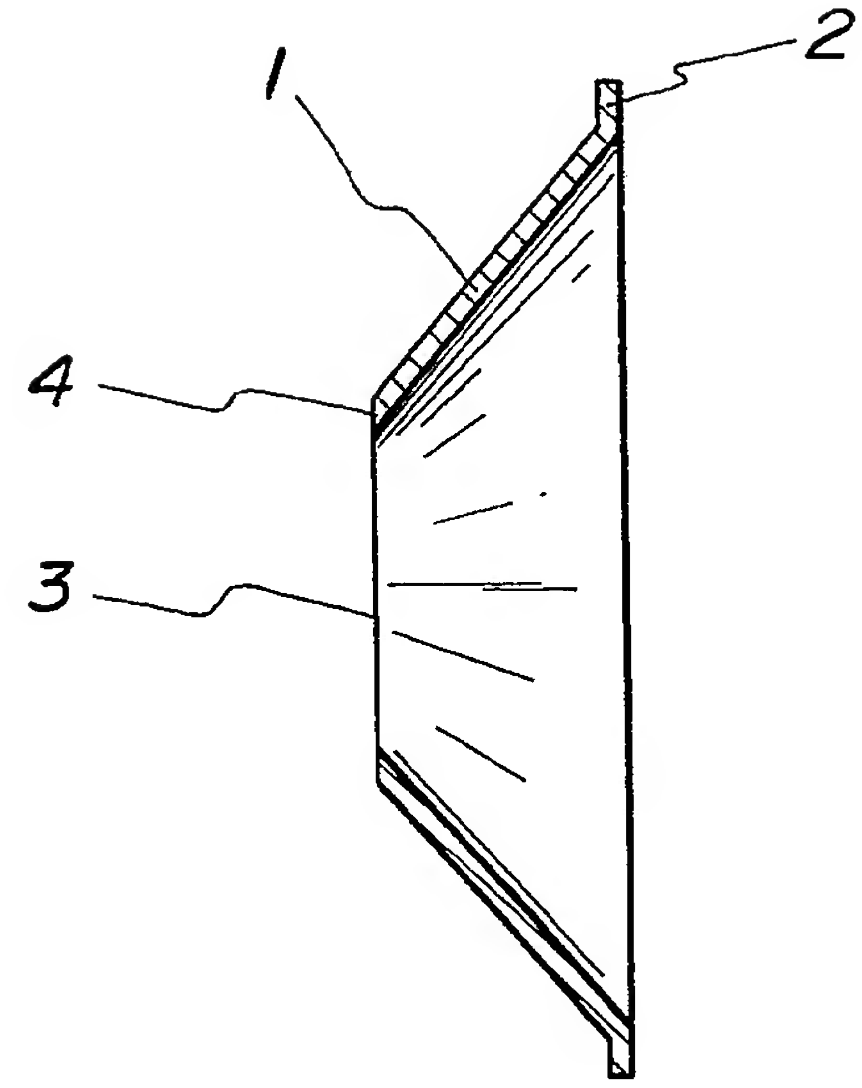

FIG. 4

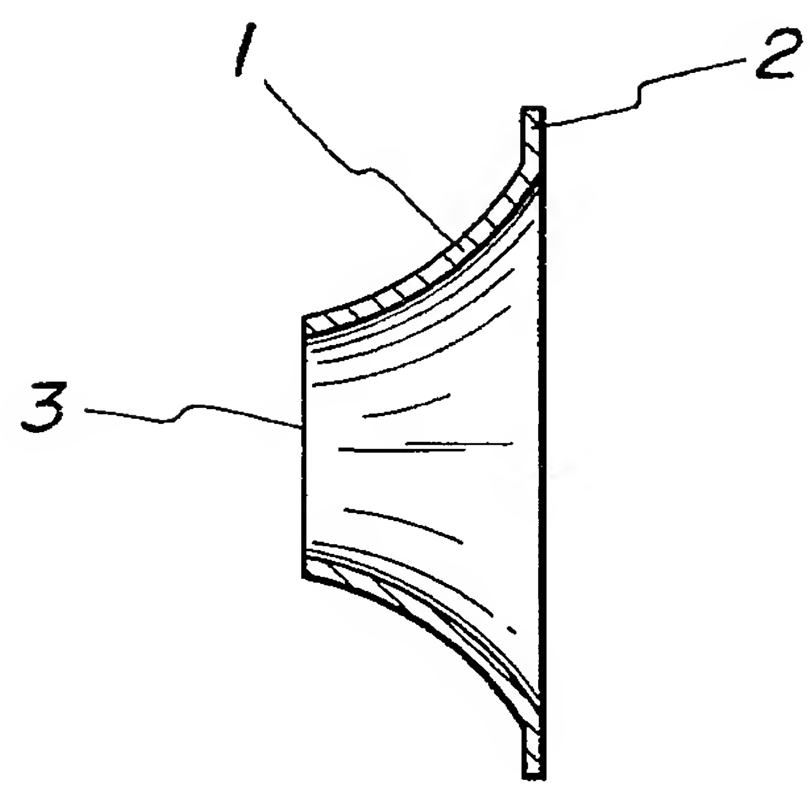

FIG. 5

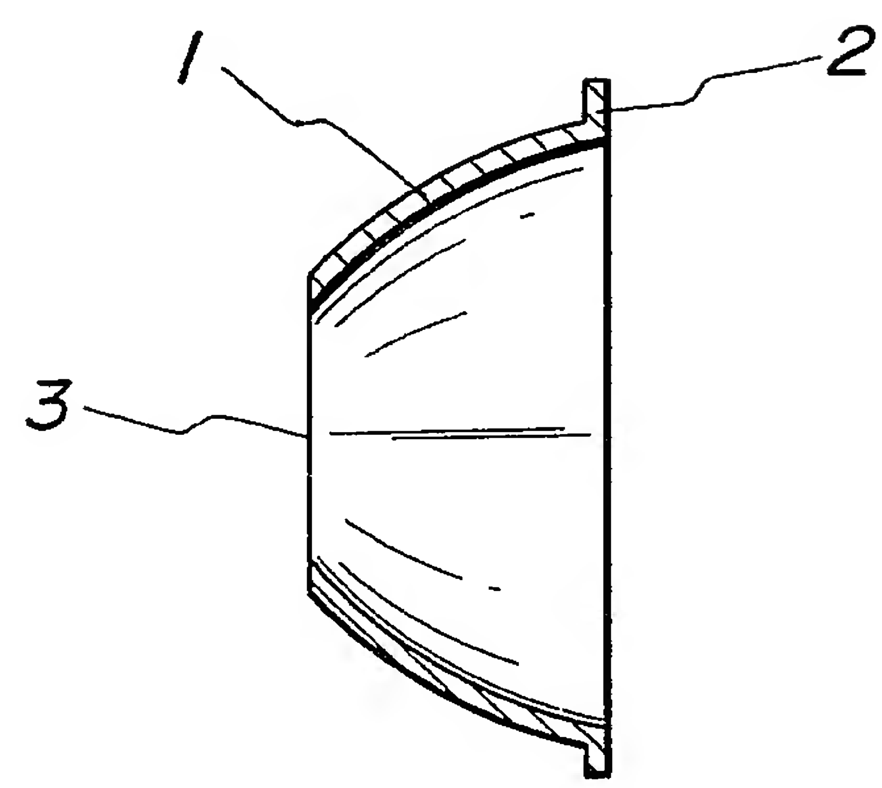

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FIG. 6

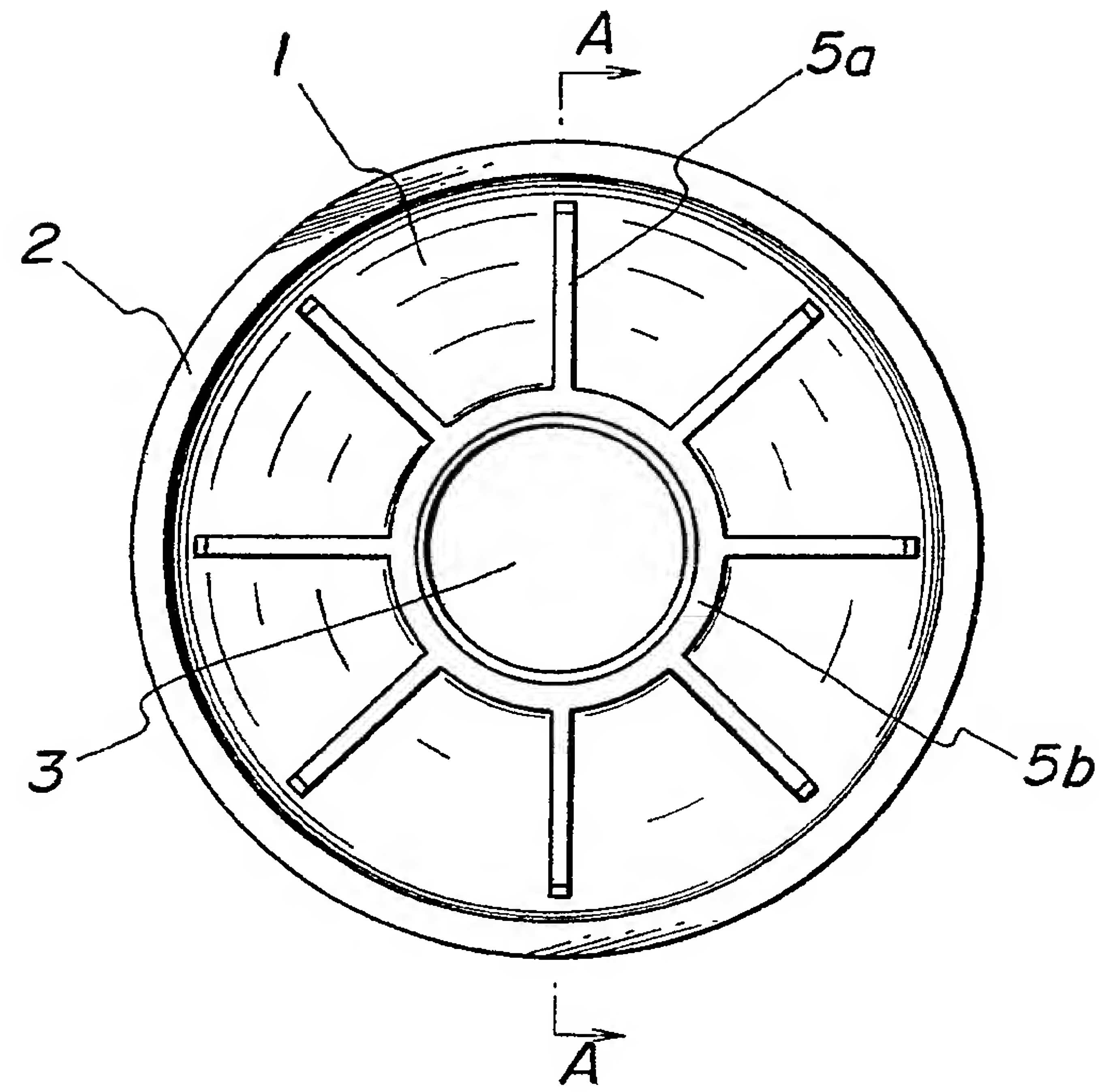


FIG. 7

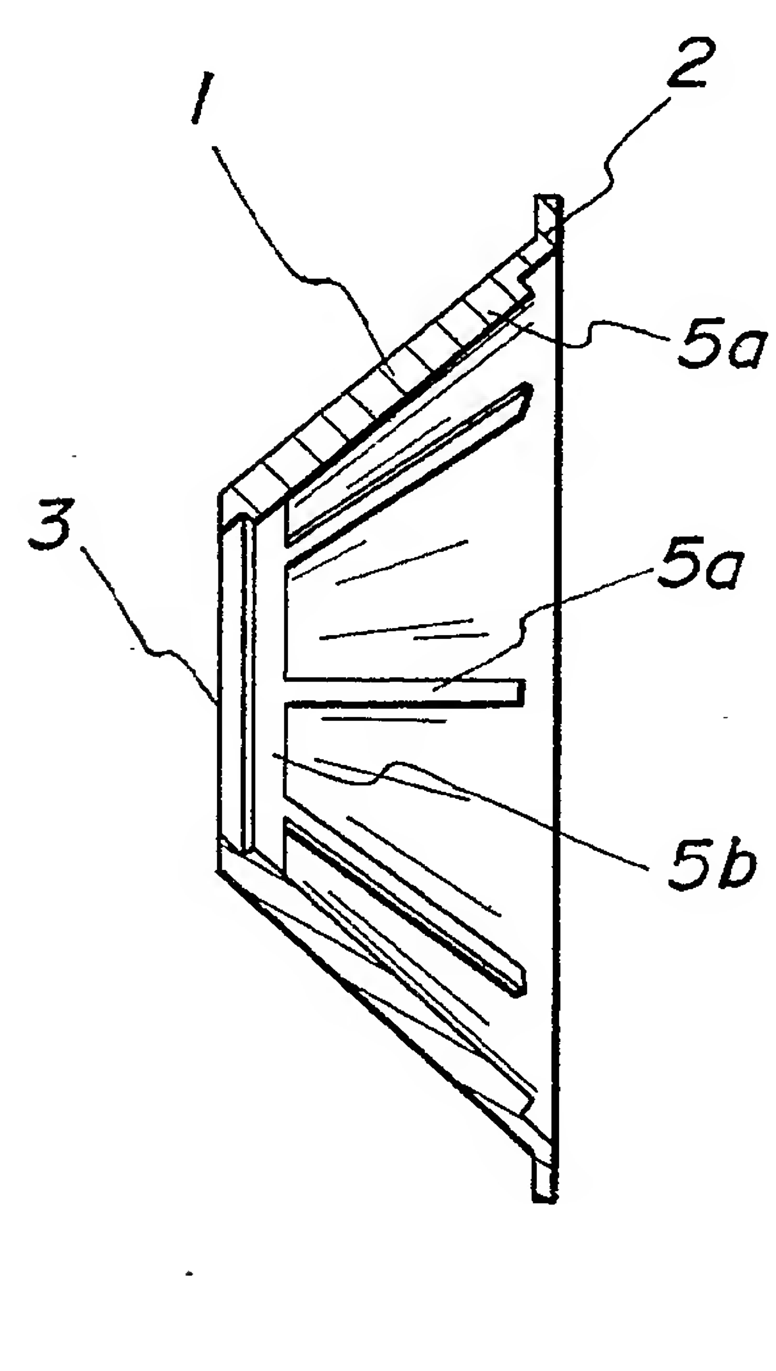


FIG. 8

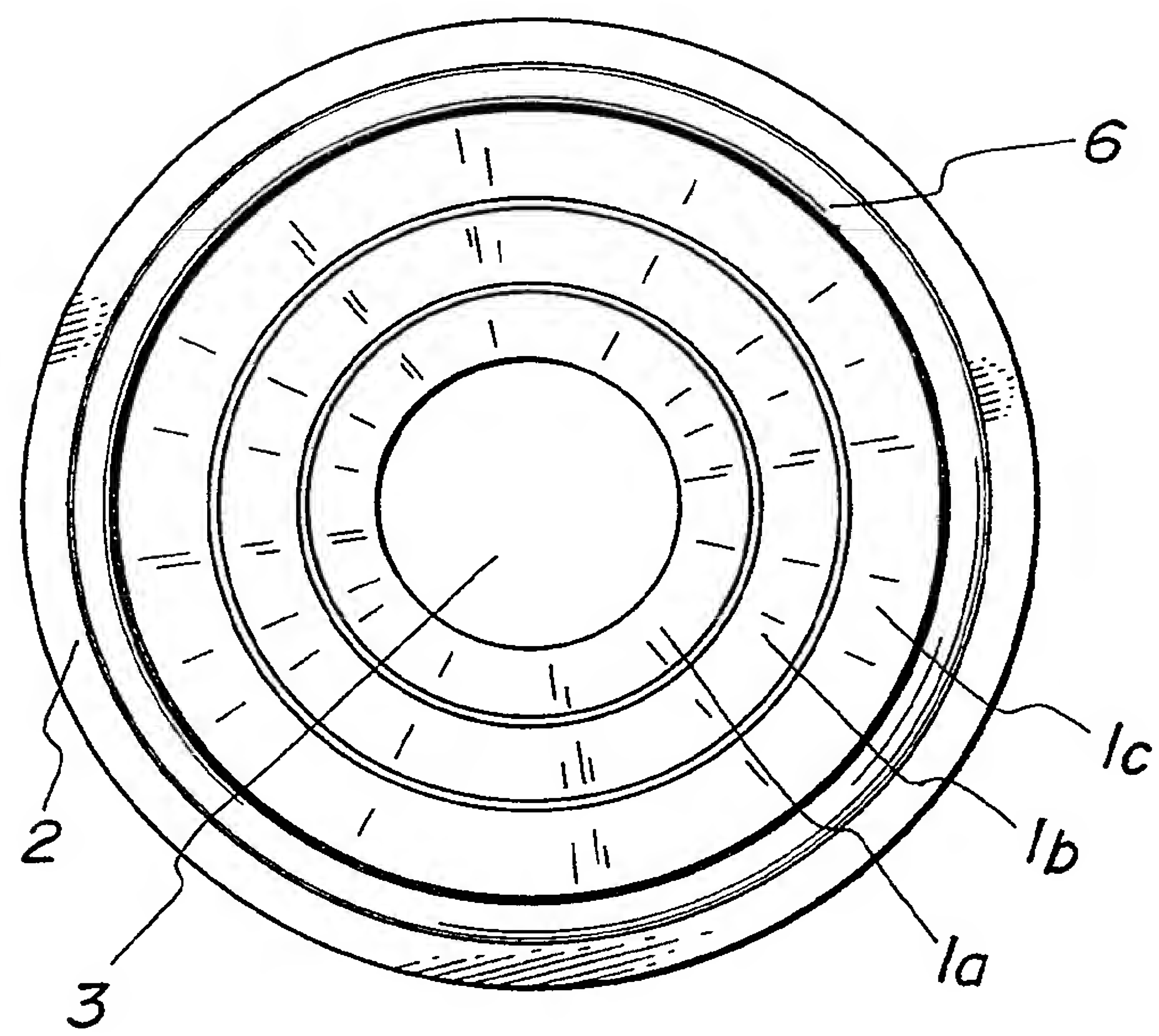


FIG. 9

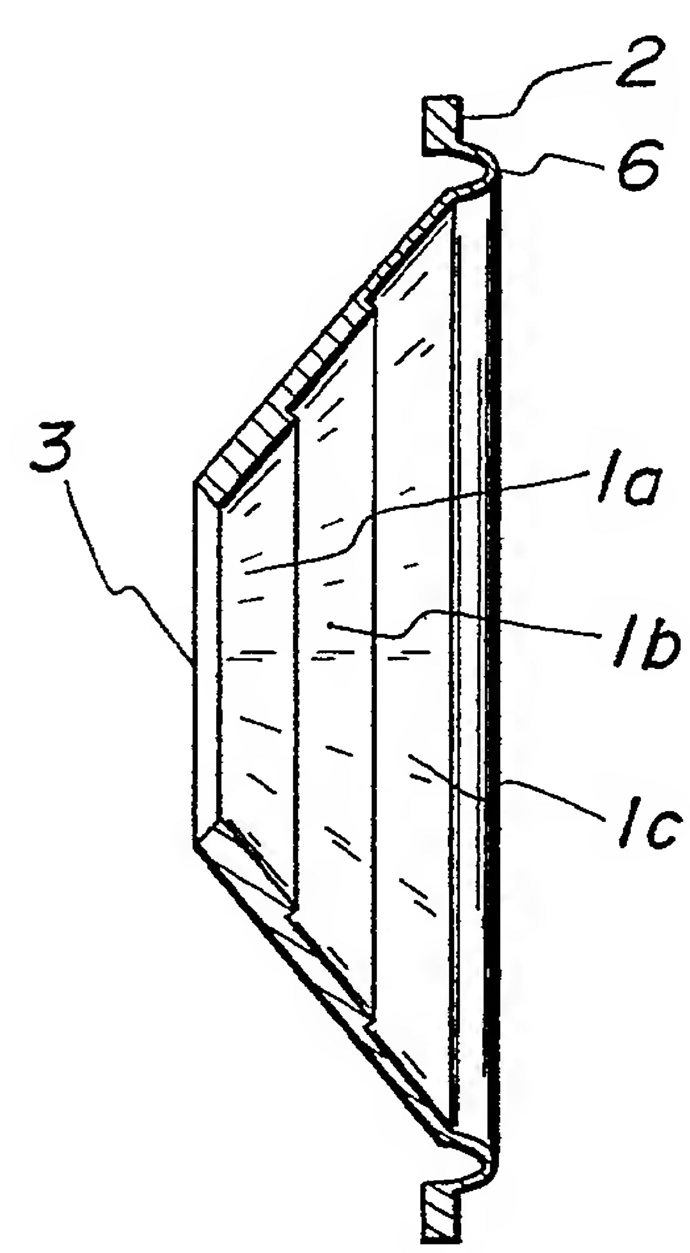


FIG. 10

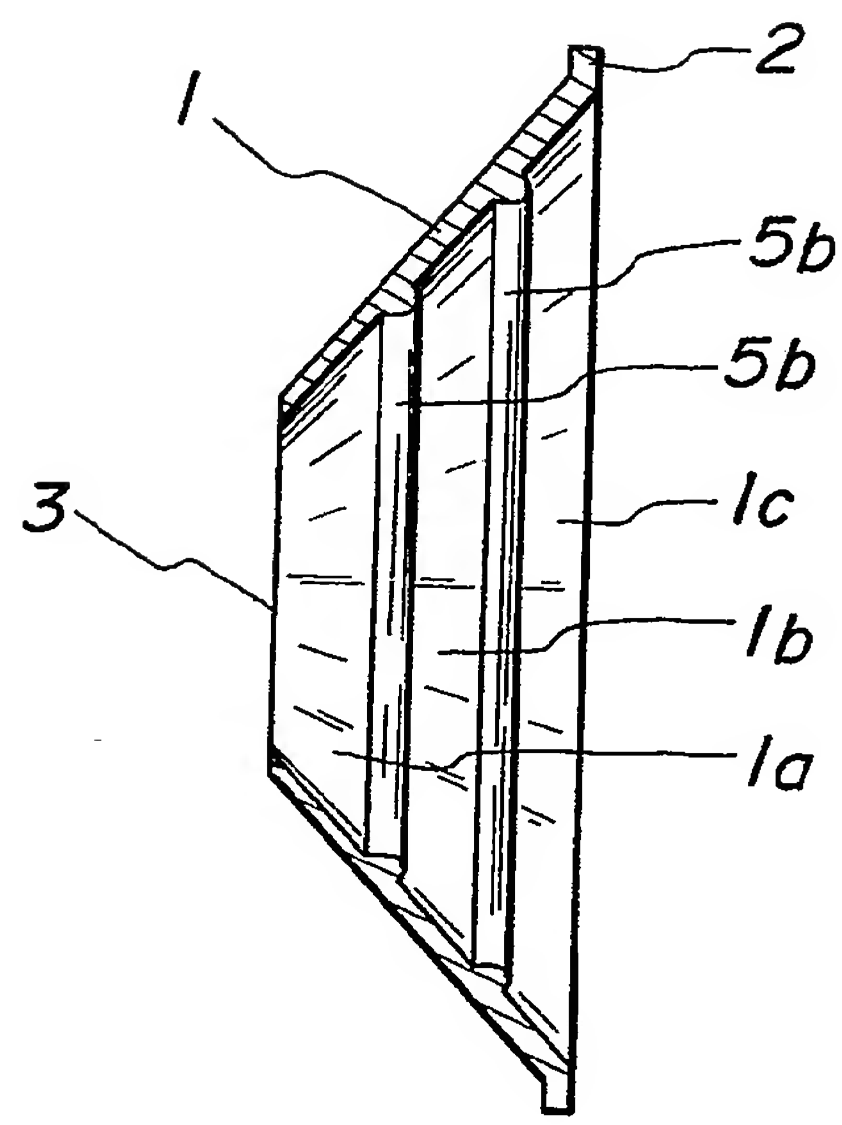


FIG. 11

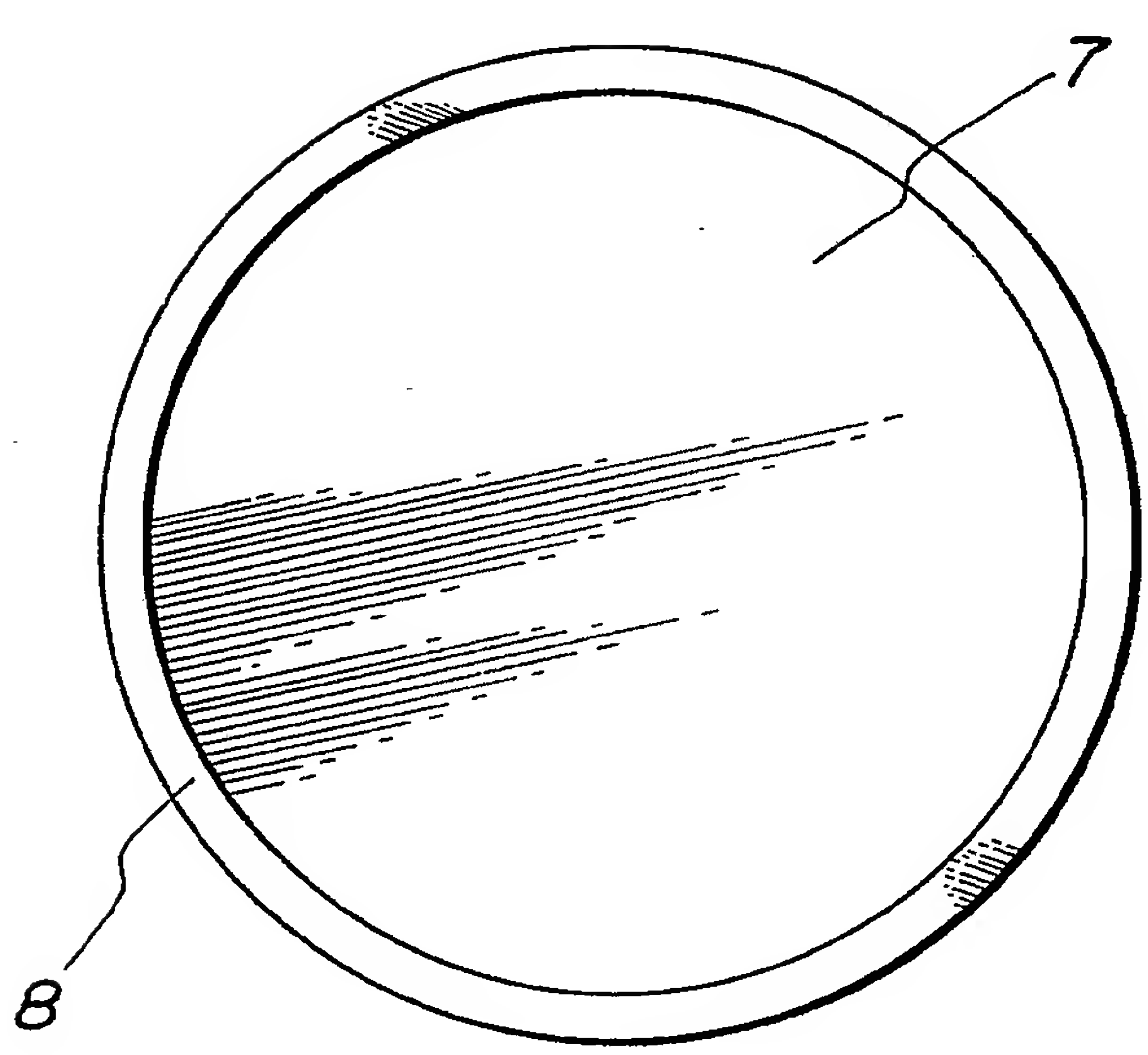


FIG. 12

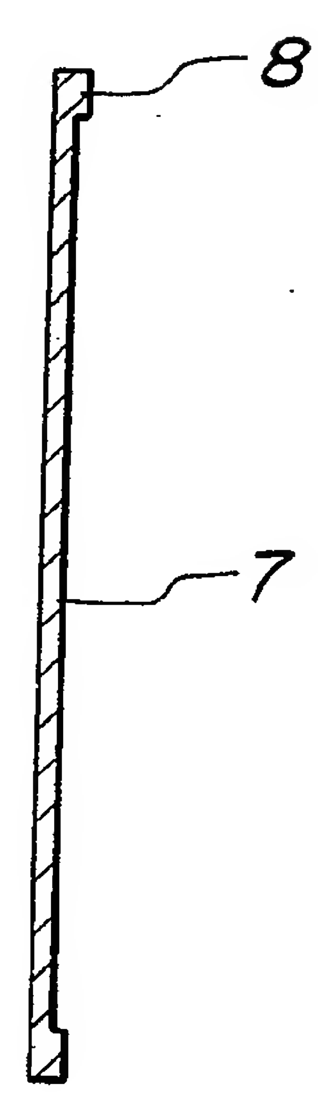


FIG. 13

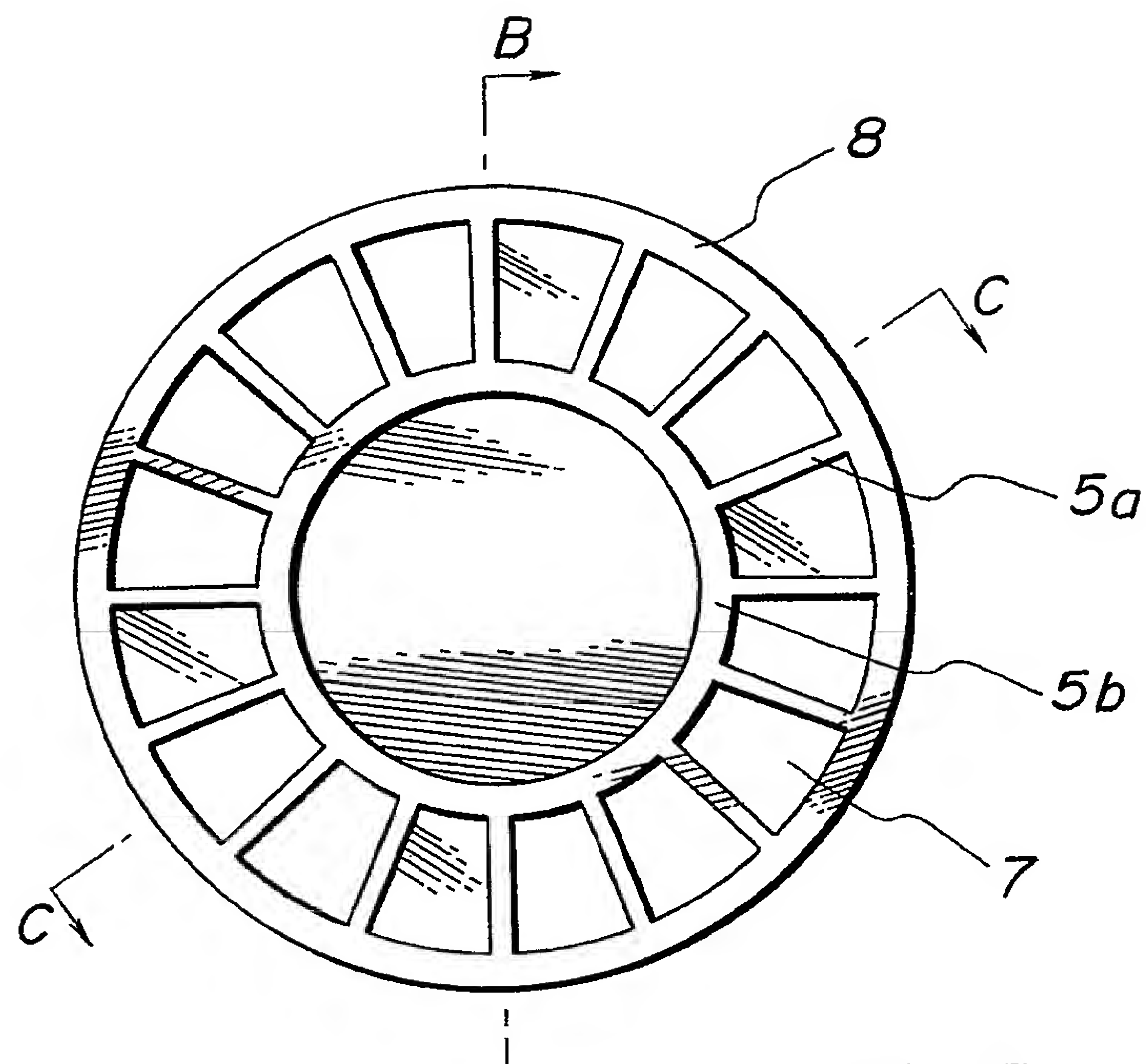


FIG. 14

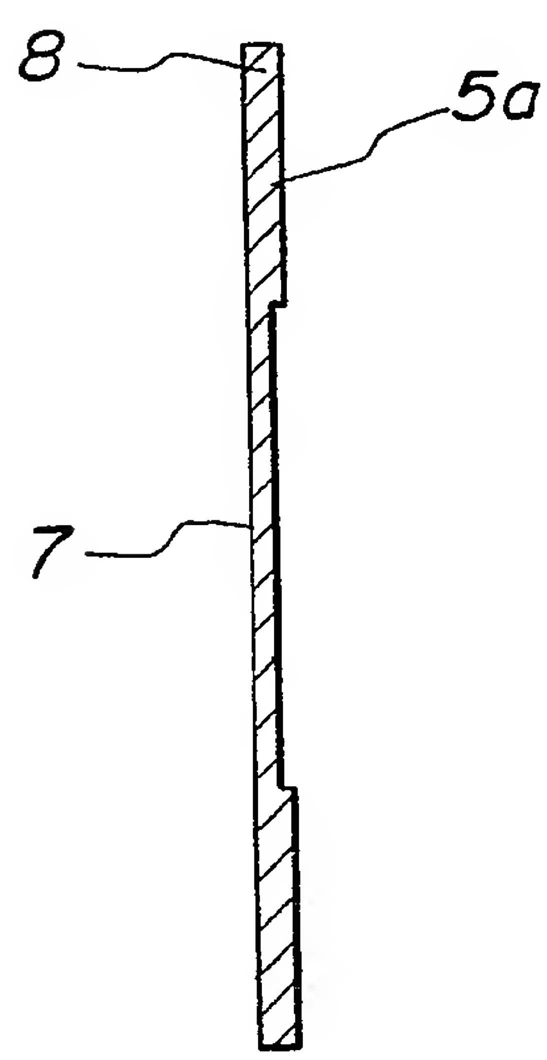


FIG. 15

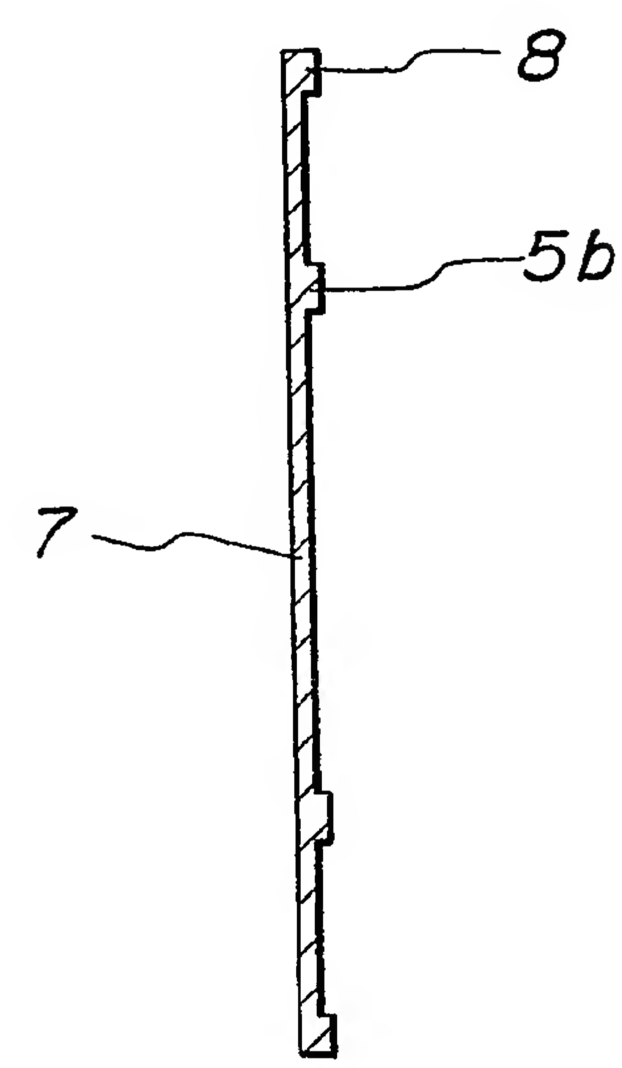


FIG. 16

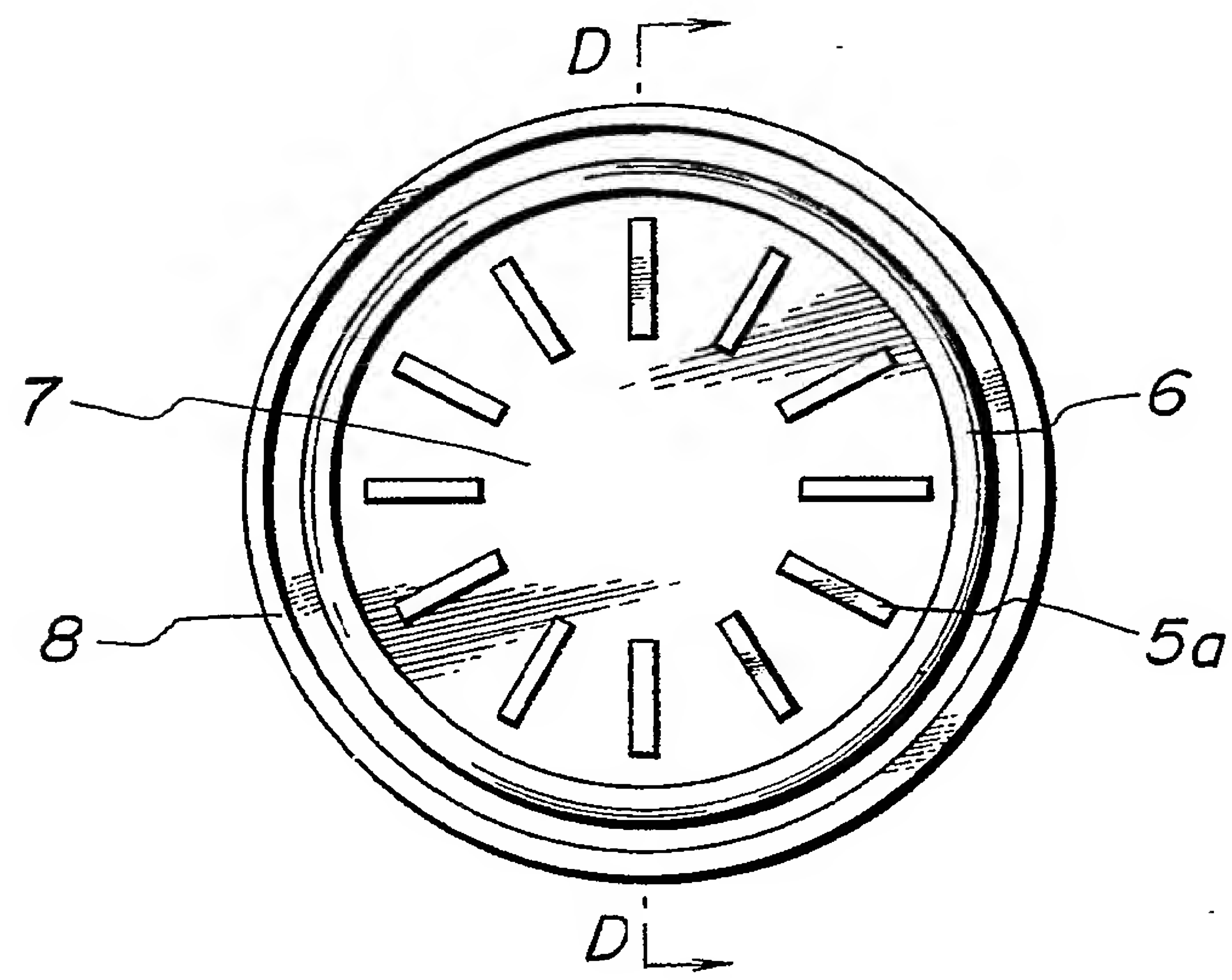


FIG. 17

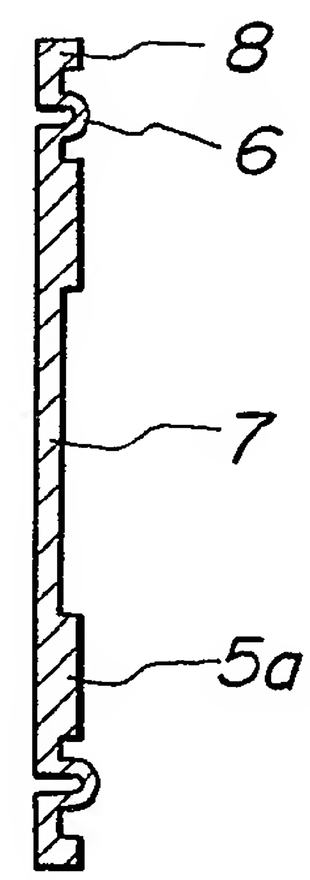


FIG. 18

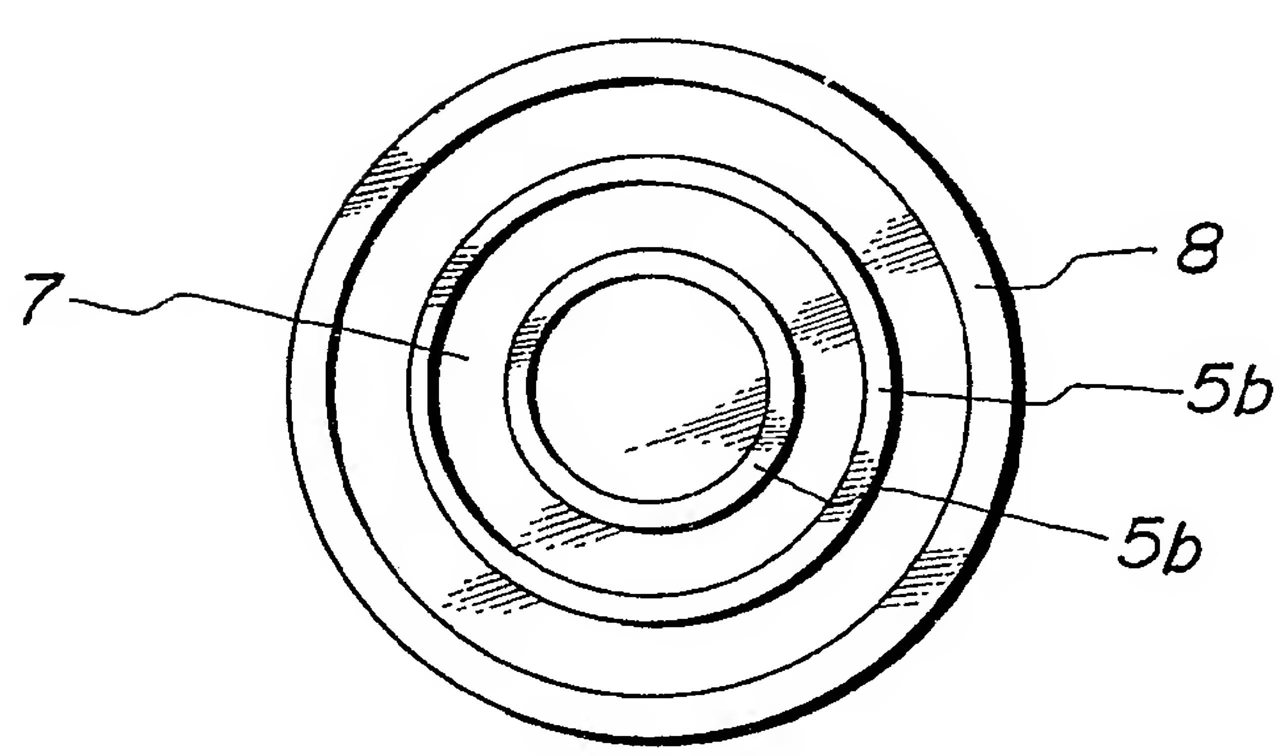
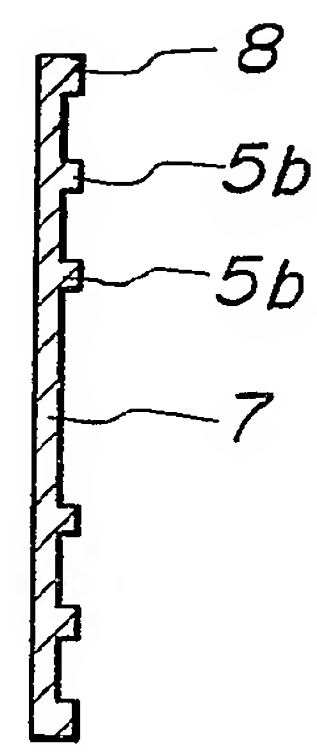


FIG. 19



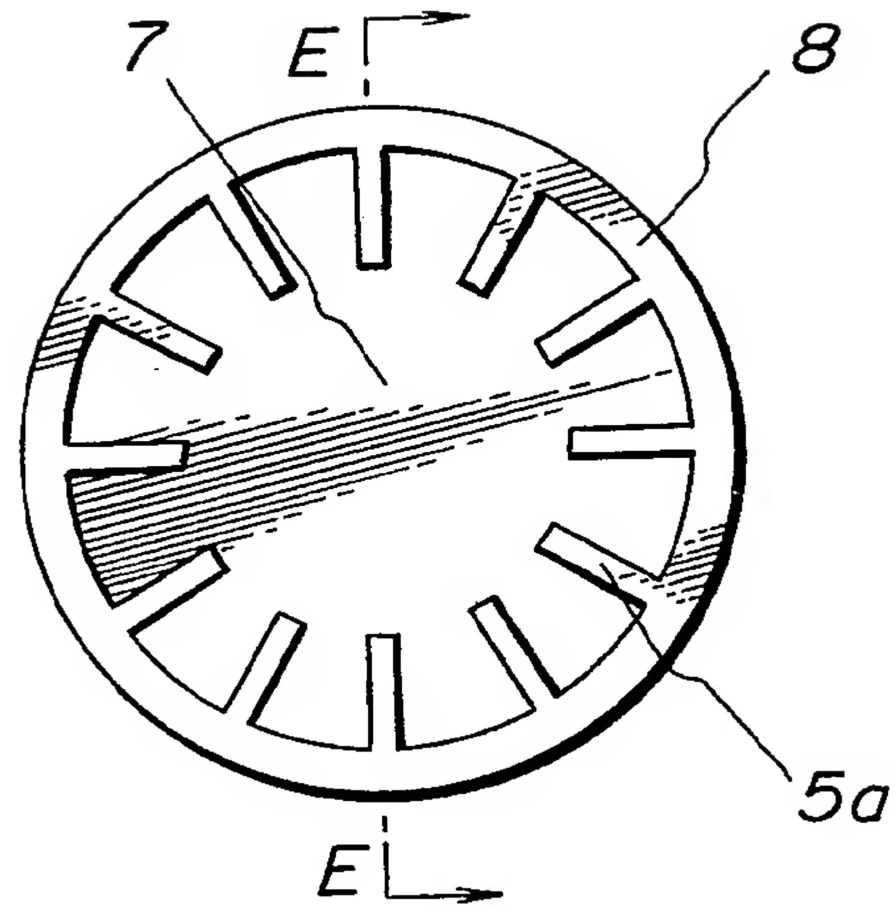


FIG.20

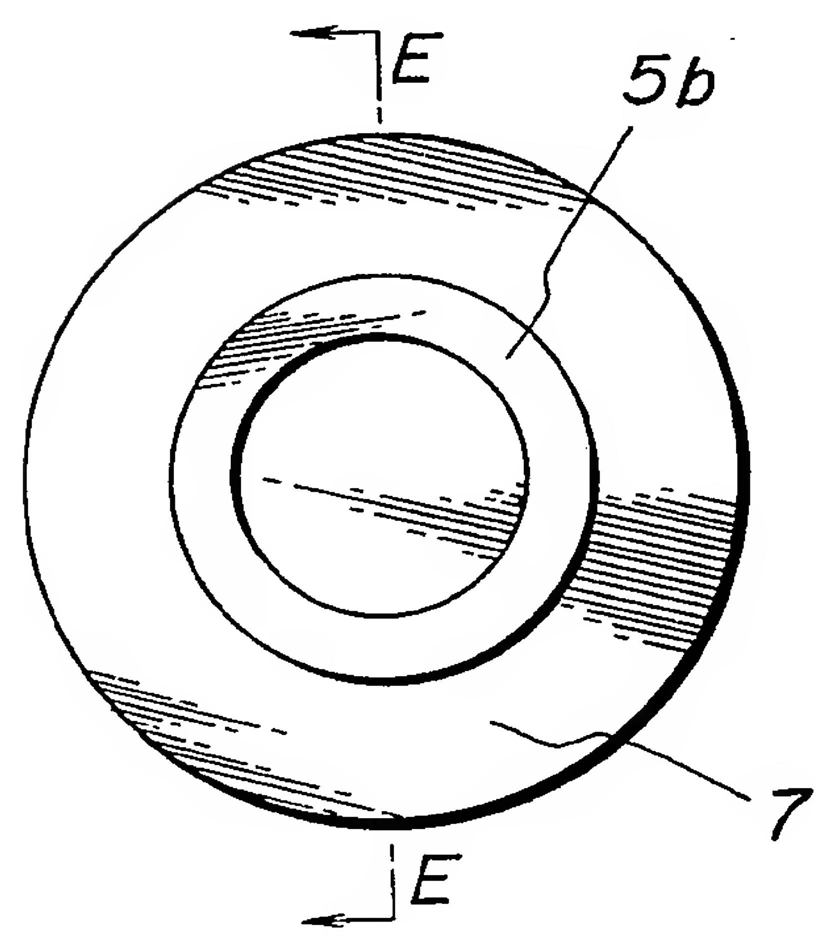


FIG. 21

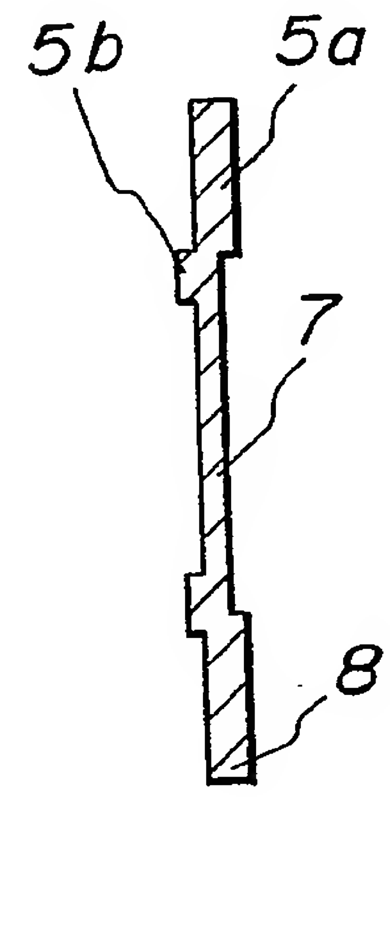


FIG. 22

FIG. 23

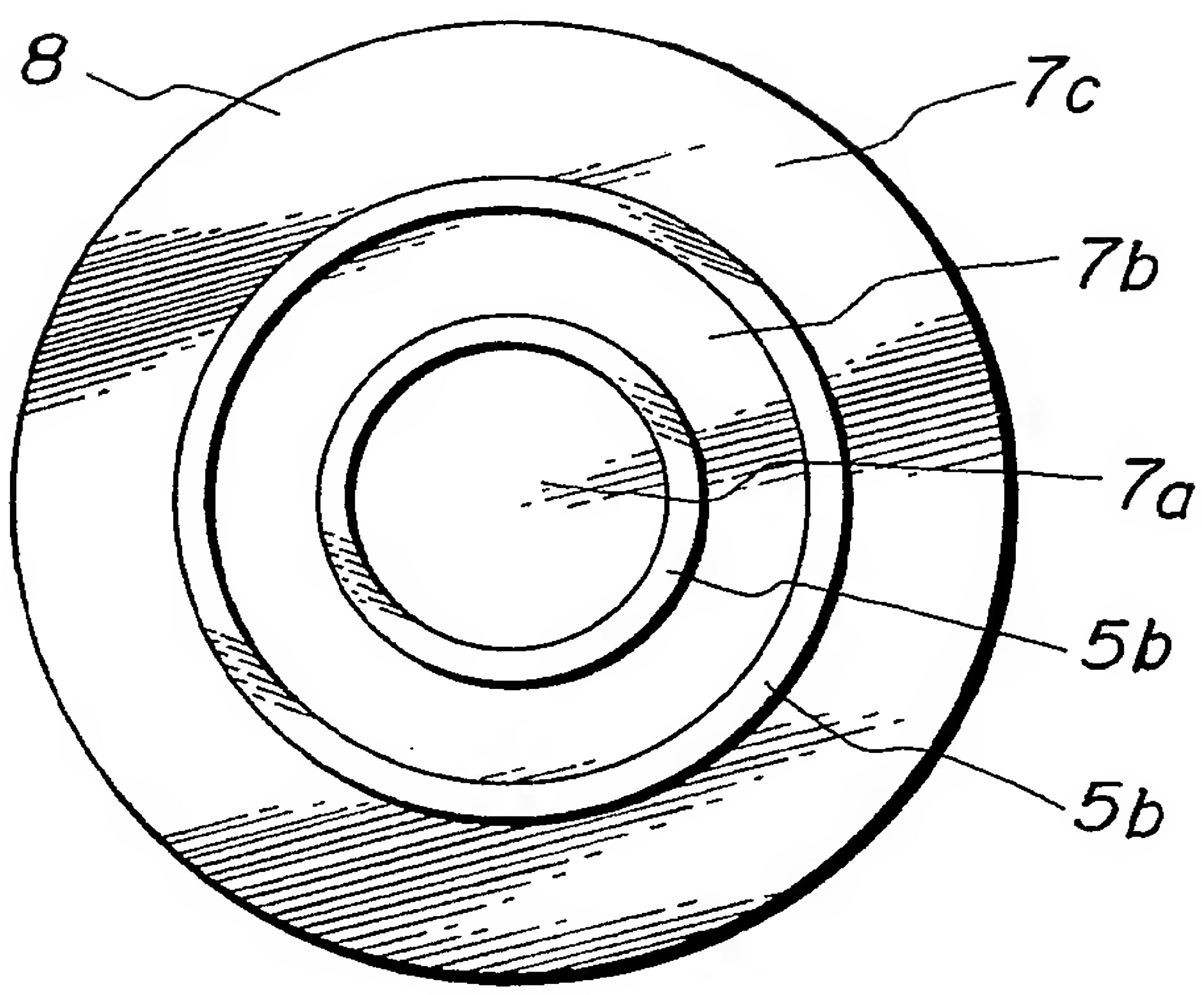


FIG. 24

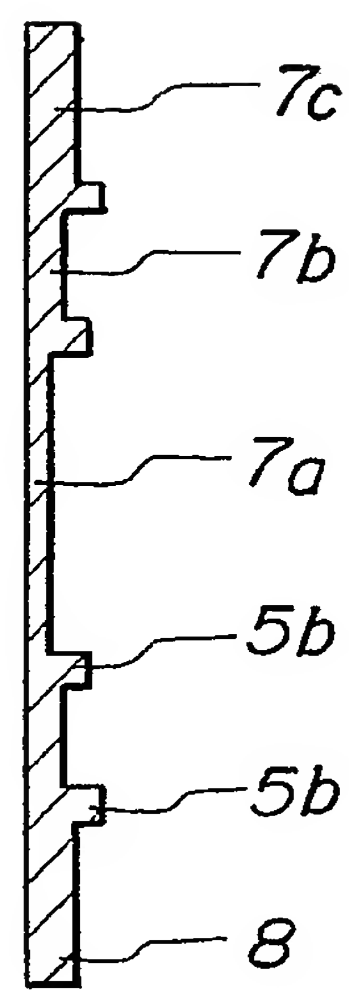


FIG. 25

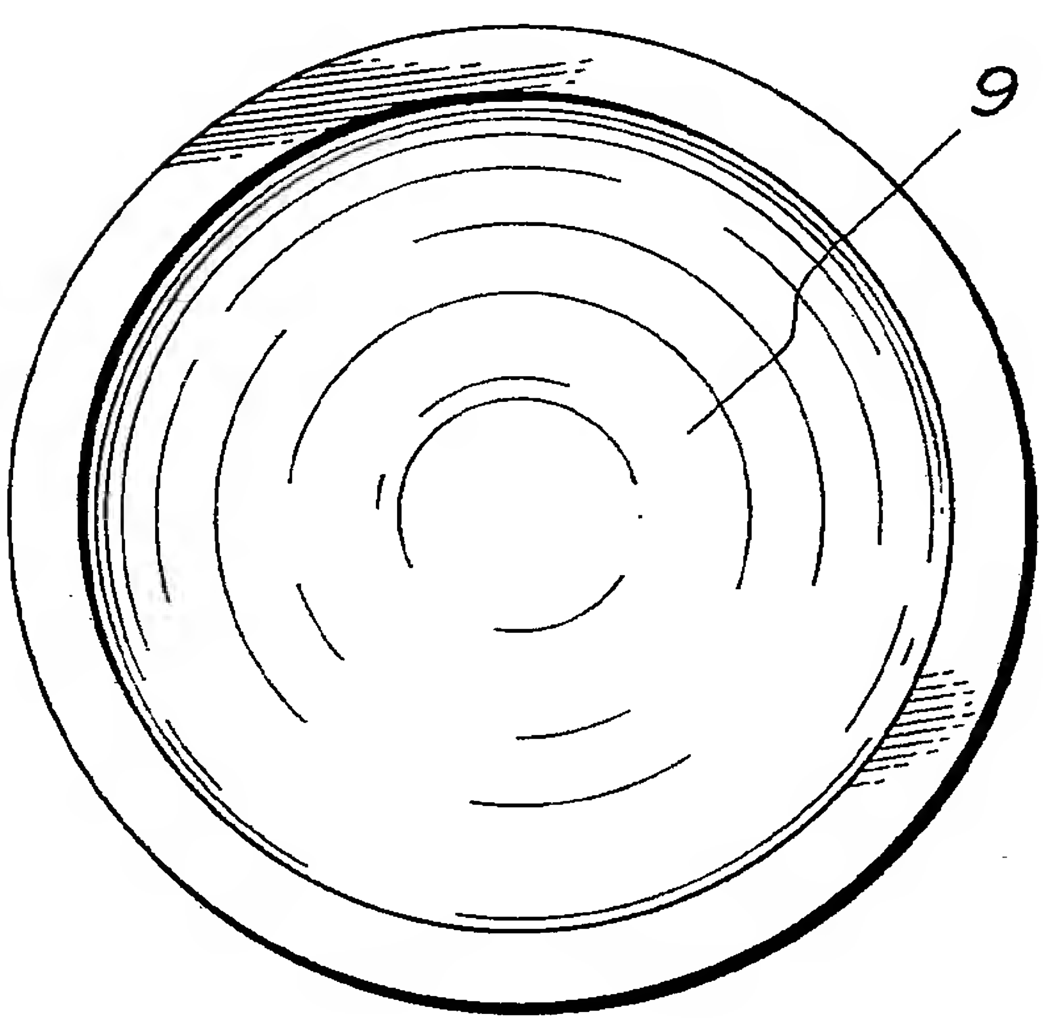
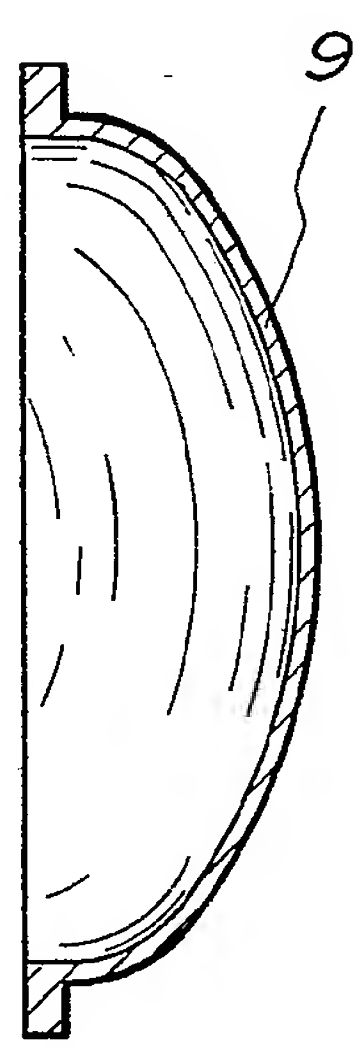


FIG. 26



SPECIFICATION

Diaphragm for loudspeaker

The present invention relates to a novel diaphragm for loudspeaker. More particularly, it relates to a diaphragm which responds faithfully to electrical inputs applied to a loudspeaker and is capable of reproducing source sounds faithfully, resulting in the reproduction of weighty sounds in the bass with no distortion and steady and clear sounds both in the mean and in the treble, and which is suitably employed for full-range speaker, woofer, tweeter and squawker, especially woofer.

Heretofore, paper diaphragms which are made of a specific paper untreated or coated or impregnated with a resin or a rubber have been used widely as a diaphragm for loudspeaker. Further there have also been known diaphragms made of an aluminum honeycomb or a foamed resin.

In the prior art, it has been recognized that all portions of a diaphragm must move like piston at the same phase as a whole and the occurrence of divisional vibration which means that individual portions of a diaphragm move with different phases is undesirable. For this reason, in case of paper diaphragms, they are strengthened by providing with corrugations or ribs to prevent the divisional vibration. Further, materials such as aluminum honeycomb and foamed resin, which have a high rigidity than paper material, have been adopted instead of paper material.

The conventional diaphragms which are based upon such a theory as mentioned above are not necessarily good in response to electrical inputs, resulting in occurrence of distortion. This tendency is marked in the bass region. Further, when a loudspeaker is operated at a high power, reverberations become remarkable so that weighty, clear reproduced sounds in the bass are hardly obtained. It is the state of things that the faithful reproduction of source sounds, especially source sounds in the bass cannot be expected when the conventional diaphragms are employed and listeners cannot enjoy a listening of a record with enriched impressions of presence. In case of paper diaphragms, there is an additional problem that change in tone quality due to moisture absorption is remarkable.

It is an object of the present invention to provide a diaphragm for loudspeaker capable of reproducing source sounds with a high fidelity while eliminating the drawbacks mentioned above.

This and other objects of the present invention will become apparent from the description hereinafter.

Fig. 1 is a perspective view of an embodiment of the diaphragm of the present invention, in which the body is cone-shaped, Figs. 2 and 3 are a plan view and a cross-sectional view of the embodiment, respectively.

Figs. 4 and 5 are cross-sectional views showing other embodiments of the cone-shaped body, respectively.

Fig. 6 is a plan view of a diaphragm in which the cone-shaped body is provided with ribs, and Fig. 7 is a cross-sectional view taken on the line A-A of Fig. 6.

Fig. 8 is a plan view of a diaphragm in which the cone-shaped body consists of portions having different thicknesses from each other, and Fig. 9 is a cross-sectional view of Fig. 8.

Fig. 10 is a cross-sectional view of other embodiment of the diaphragm in which the cone-shaped body consists of portions having different thicknesses from each other.

Fig. 11 is a plan view of a diaphragm in which the body is flat plate-shaped and Fig. 12 is a cross-sectional view of Fig. 11.

Fig. 13 is a plan view of a diaphragm in which the flat plate-shaped body is provided with ribs, Fig. 14 is a cross-sectional view taken on the line B-B of Fig. 13, and Fig. 15 is a cross-sectional view taken on the line C-C of Fig. 13.

Fig. 16 is a plan view of other embodiment of the diaphragm in which the flat plate-shaped body is provided with ribs, and Fig. 17 is a cross-sectional view taken on the line D-D of Fig. 16.

Fig. 18 is a plan view of another embodiment of the diaphragm in which the flat plate-shaped body is provided with ribs, and Fig. 19 is a cross-sectional view of Fig. 18.

Fig. 20 is a plan view of still another embodiment of the diaphragm in which the flat plate-shaped body is provided with ribs, Fig. 21 is a plan view of the opposite side of the embodiment, and Fig. 22 is a cross-sectional view taken on the line E-E of Figs. 20 and 21.

Fig. 23 is a plan view of a diaphragm in which the flat plate-shaped body consists of portions having different thicknesses from each other, and Fig. 24 is a cross-sectional view of Fig. 23.

Fig. 25 is a plan view of a diaphragm in which the body is dome-shaped, and Fig. 26 is a cross-sectional view of Fig. 25.

The present invention is to provide a diaphragm for loudspeaker comprising of a cured molding of a rubber.

The present invention has been accomplished on the basis of a novel theory that the whole of a diaphragm does not necessarily move at the same phase like piston, which breaks down the preconceived idea as mentioned above.

The conventional diaphragm is constructed so that the body of the diaphragm with a high rigidity is provided with a flexible edge at the periphery thereof and the body moves like piston at the same phase as a whole due to the presence of the edge. To the contrary, the diaphragm of the present invention is constructed so that the body is made of a cured rubber and has a low rigidity and the body having such a low rigidity is allowed to vibrate freely without particularly forcing the body to move at the same phase as a whole. In case of the diaphragm of the present invention, therefore, it is not particularly necessary to provide the body with an edge. In this aspect, the diaphragm of the present invention, so to say, should be called "artificial vocal chords".

It has been found out that the diaphragm of the present invention on the basis of such a novel theory unexpectedly has a good response characteristic to electrical inputs applied to a loudspeaker and reproduces faithfully source sounds, whereby giving

weighty reproduced sounds in the bass with no distortion and steady and clear reproduced sounds in the mean and in the treble. In particular, the diaphragm of the present invention has an excellent damping characteristic and even when a high input power in the bass region is applied to the loudspeaker, reverberations do not almost remain to give clear and weighty reproduced sounds in the bass region. Further the diaphragm of the present invention has an excellent humidity resistance, differing from the conventional paper diaphragm and shows no change in tone quality due to moisture absorption.

Another important characteristic of the diaphragm of the present invention is that a loudspeaker employing the diaphragm of the present invention can give a high output power in the bass region even when its caliber is small. In case of a loudspeaker employing the conventional diaphragm, a caliber of not less than 30 cm., ideally up to about 2 m. is required to obtain weighty reproduced bass sounds. However, a loudspeaker employing the diaphragm of the present invention, even if its caliber is about 15 cm., gives a weighty bass sound comparable to that obtained by a conventional loudspeaker having a caliber of 30 cm. or more. When the caliber of a loudspeaker is small, the enclosure therefor can be miniaturized, which results in the reduction of cost of speaker system and the easy selection of a place where the speaker system is located.

From the above viewpoint, the diaphragm of the present invention is particularly useful for woofer. Of course, it is also applied to full-range speaker, squawker and tweeter.

Further, in case of a loudspeaker employing the diaphragm of the present invention, it is unnecessary to fill the enclosure of the loudspeaker with an absorbing material such as glass fiber or felt. It is estimated that this advantage is responsible for the above-mentioned specific vibration mode of the diaphragm of the present invention.

Still another characteristic of the diaphragm of the present invention is that it has a characteristic in appearance in addition to the acoustic characteristic mentioned above. As described above, the vibration mode of the conventional diaphragm is so monotonous that the diaphragm mainly moves forward and backward like piston. To the contrary, the vibration mode of the diaphragm of the present invention is so complicated that it vibrates as a wave undulates in addition to a forward and backward movement. Such vibrations change momentarily during the playback of a disk record, which causes a person, who looks at the diaphragm, to hold a feeling that the diaphragm would have a facial expression and the facial expression changes momentarily. From this viewpoint, a loudspeaker employing the diaphragm of the present invention is preferably employed without covering with a front cover.

The cured rubber employed in the present invention is not particularly limited with respect to its physical properties, composition, etc. and they may be suitably selected, for instance, depending upon the kind of a loudspeaker to which the diaphragm is mounted, such as full-range speaker, woofer, squawker or tweeter.

Usually there is employed a cured rubber having a hardness of not more than 80° as measured with an A-type rubber hardness tester and not less than 15° as measured with an F-type rubber hardness tester and an impact resilience of not less than 40 %. There is preferably employed a cured rubber having a tensile strength of 0.1 to 200 kg./cm^2., an elongation of 20 to 1,000 % and a specific gravity of 0.8 to 1.5 in addition to the above-mentioned physical properties.

In the foregoing, the A-type rubber hardness tester is a rubber hardness tester provided in JIS K 6301-1969. Further, the F-type rubber hardness tester means Asker F-type rubber hardness tester made by Kobunshi Keiki Mfg. Co., Ltd., which is mainly used for measurements of hardness of foam rubber, urethane foam or the like. Despite that the cured rubber employed in the present invention is a solid rubber, the hardness of some of the cured rubber is very low and is unmeasurable by means of the A-type rubber hardness tester which is used in measuring hardness of usual solid rubbers. To this end, the lower limit of hardness of the cured rubber employed in the present invention is defined by the hardness value as measured with the F-type rubber hardness tester.

An intermediate hardness between the measuring range of the A-type rubber hardness tester and that of the F-type rubber hardness tester may be measured with a C-type rubber hardness tester. The C-type rubber hardness tester as used herein means one provided in the Society of Rubber Industry Japan Standard SRIS-0101 and used to measure such intermediate hardnesses between the measuring ranges of the A-type and F-type rubber hardness testers. The C-type rubber hardness tester is mainly used to measure the hardness of sponge, soft rubber or the like. As the C-type rubber hardness tester, Asker C-type rubber hardness tester made by Kobunshi Seiki Mfg. Co., Ltd. is used.

The hardness of the cured rubber employed in the present invention may be determined with any of the A-type rubber hardness tester, the C-type rubber hardness tester and the F-type rubber hardness tester, if the measurement is possible with any of these rubber hardness testers. However, if a hardness as measured with the A-type rubber hardness tester is not more than 1°, it is preferable to measure the hardness with either the C-type rubber hardness tester or the F-type rubber hardness tester because an error in measurement with the A-type rubber hardness tester is large. Similarly, if a hardness as measured with the C-type rubber hardness tester is not more than 1°, it is preferable to measure the hardness with the F-type rubber hardness tester. Also, if a hardness as measured with the C-type rubber hardness tester is not less than 99°, it is preferable to measure the hardness with the A-type rubber hardness tester. Similarly, if a hardness as measured with the F-type rubber hardness tester is not less than 99°, it is preferable to measure the hardness with the C-type rubber hardness tester or the A-type rubber hardness tester. The hardness values measured with the A-type rubber hardness tester, the

C-type rubber hardness tester and the F-type rubber hardness tester will hereinafter be referred to as *A* hardness, *C* hardness and *F* hardness, respectively.

The rubber composition from which the cured rubber mentioned above is obtained is also particularly limited and, for instance, includes one which comprises (A) 100 parts (parts by weight, the same hereinafter) of a rubber component, (B) 0 to 2,000 parts of a factice and (C) 0 to 2,000 parts of a softening agent (provided that a case wherein both the amount of the component (B) and that of the component (C) are zero is excepted).

As the rubber component (A), there are exemplified polynorbornene, natural rubber, isoprene rubber, chloroprene rubber, styrene-butadiene rubber, butadiene rubber, butyl rubber, ethylene-propylene rubber, ethylene-propylene-diene rubber, nitrile rubber, acryl rubber, urethane rubber, chlorinated polyethylene, chlorosulfonated polyethylene, epichlorohydrin rubber, polysulfide rubber, silicone rubber and the like. Regenerated rubbers of these rubber components (for example, rubber powder or the like) are also included. These rubber components may be either in the form of solid (powder, pellet, block, sheet, etc.) or in the form of liquid (liquid rubber, latex, etc.). Also, the above rubber components may be employed alone or in admixture of two or more kinds of them.

As a factice of the component (B), there are employed any of various kinds of factices such as white factice, black factice, amber factice and blue factice which are obtained by vulcanizing a variety of vegetable oils including linseed oil, rapeseed oil, soybean oil, sesame oil, tung oil and castor oil with sulfur or sulfur chloride. These factices may be used alone or in admixture. The factice obtained by vulcanizing rapeseed oil is particularly favorable.

The softening agent as the component (C) includes oils, plasticizers and other agents having a softening activity. As oils, there are employed any of filling oils for rubbers usually employed (as a softening oil, process oil, etc.) such as aromatic oils, naphthenic oils, paraffinic oils, vegetable oils and animal oils and the like. The vegetable oils and animal oils mentioned above include castor oil, rapeseed oil, linseed oil, whale oil, fish oil and the like. As plasticizers, there can be used any of those having a high softening performance out of plasticizers usually used as plasticizers for rubbers. For example, there are exemplified dibutyl phthalate, dioctyl phthalate, dioctyl sebacate, and the like. As other softening agents, liquid rubbers are mentioned. The softening agents mentioned above may be used alone or in admixture of two or more kinds thereof. Usually oil alone or a mixture of an oil and a plasticizer is preferably employed.

To the above-mentioned rubber composition there may be suitably added further rubber additives usually employed, e.g. fillers such as carbon black and zinc oxide, colorants, lubricants such as stearic acid and antioxidants.

For curing of the above rubber composition, any of usual curing systems can be used. Both sulfur curing and sulfurless curing may be used. The curing conditions, etc. are not particularly limited and usual conditions are adopted.

Generally a cured rubber having a higher hardness is employed to produce a diaphragm for the reproduction of treble sounds and a cured rubber having a lower hardness is employed to produce a diaphragm for the reproduction of bass sounds. Usually a cured rubber having a hardness of not less than 20° in *A* hardness is employed for squawker and tweeter and a cured rubber having a hardness of not more than 30°, preferably not more than 20° in *A* hardness is employed for woofer.

In the present invention, it has been found out that a cured rubber having a hardness within the range of an *A* hardness of not more than 30°, especially not more than 20° and an *F* hardness of not less than 15°, especially not less than 30° and an impact resilience of not less than 50 %, especially from 60 to 95 %, if necessary, further having a tensile strength of 0.1 to 100 kg./cm$_{2}$., especially 1 to 50 kg./cm$_{2}$., an elongation of 100 to 1,000 %, especially 200 to 1,000 % and a specific gravity of 0.8 to 1.3, especially 0.89 to 1.1 is useful for diaphragms for woofer, squawker and full-range speaker, particularly woofer. The diaphragms made of such a specific cured rubber are particularly able to give bass sounds faithful to source sounds.

The above specified cured rubber is a novel rubber material which has not been known hereinafter. That is, in the case of conventional cured rubbers, those with a hardness of not more than 30° in *A* hardness have an impact resilience of less than 40 %, and those with an impact resilience of not less than 40 % have a hardness of more than 30° in *A* hardness. It is common knowledge that the impact resilience of cured rubber decreases with a decrease of its hardness. The physical properties of the above specific cured rubber, i.e. an *A* hardness of not more than 30°, especially not more than 20° and an impact resilience of not less than 50 %, especially from 60 to 95 %, are definitely outside of the prior common concept.

The cured rubber having the above specific physical properties can be obtained by curing a rubber composition which comprises (A) 100 parts of a rubber component, (B) 5 to 2,000 parts, preferably 20 to 1,500 parts, more preferably 100 to 1,500 parts of a factice and (C) 20 to 2,000 parts, preferably 200 to 1,500 parts of a softening agent. Such a rubber composition obtained by adding large amounts of a factice and a softening agent to a rubber component is a new rubber composition. Only by curing such a new rubber composition, there can be obtained a particular cured rubber having a hardness of not more than 30°, particularly not more than 20° in *A* hardness and not less than 15°, particularly not less than 30° in *F* hardness and an impact resilience of not less than 50 %, particularly from 60 to 95 %.

In the above rubber composition, a rubber component composed predominantly of polynorbornene is preferred as the rubber component (A). When a mixture of polynorbornene and other rubber component is employed, it is desirable that the proportion of polynorbornene is not less than 50 % (% by weight, the same hereinafter), particularly not less than 65 %.

Showing a typical formulation of the above-mentioned specific rubber composition with taking the case of sulfur curing as an example, it is as follows:

(Component)	(Parts)
Rubber component	100
Factice	20 to 1,500
Softening agent	200 to 1,500
Filler	1 to 200
Antioxidant	0.5 to 6
Sulfur	0.5 to 10
Curing accelerator	1 to 20

The shape of the diaphragm of the present invention is not particularly limited and any of shapes of conventional diaphragms can be adopted. Preferable shapes are as follows:

Fig. 1 is a perspective view of an embodiment of the diaphragm of the present invention, Fig. 2 is a plan view of the embodiment and Fig. 3 is a cross-sectional view of the embodiment. Numeral 1 is the body of a cone-shaped diaphragm, numeral 2 is a fitting portion directly joined to the outer periphery of the body 1 without interposing an edge between them, and numeral 3 is an opening. The body 1 is attached to the flame of a speaker at the fitting portion 2. To the inner periphery 4 of the body 1 there is attached a voice coil. The opening 3 is covered with a cap.

The conical shape of the body 1 is not limited to straight cone as shown in Figs. 1 to 3 and other various shapes such as hyperbolic or exponential cone shown in Fig. 4 (cross-sectional view) and a parabolic cone shown in Fig. 5 (cross-sectional view) are adopted. The shape in plan (the shape viewed from the front, the same hereinafter) of the body 1 is not limited to circular shape shown in Fig. 2 and other shapes such as elliptical shape and polygonal shape (which includes polygons such as triangle, tetragon, pentagon, hexagon and so on, and the polygons may be regular one or modifications thereof, the same hereinafter) may be adopted.

The body 1 may be provided with ribs. The ribs serve as a reinforcing element when the body 1 is thin. However, the ribs do not only serve as reinforcing element but also participate in the tone quality of reproduced sounds. For instance, they improve damping characteristics. The ribs are, for instance, provided in such a manner as shown in Fig. 16 (plan view) and Fig. 7 (cross-sectional view taken on the line A-A of Fig. 6). The ribs shown in Figs. 6 and 7 consist of radial ribs 5a and a concentrically circular rib 5b.

When the shape in plan of the body 1 is shapes other than circle, the concentrically circular rib 5b can be transformed in correspondence with the shape of the body 1. The concentrically circular rib 5b intended in the present invention includes such transformed shapes.

Either the radial ribs 5a or the concentrically circular rib 5b may be omitted. The number, the pattern, etc. of the ribs 5a and 5b may be suitably decided in consideration of the strength and the caliber of the body 1 and the desired tone quality. The ribs 5a and 5b may be provided on the obverse of the body 1 or on the reverse of the body 1, or on both surfaces.

According to another embodiment, the ribs 5a are provided on the obverse and the rib 5b on the reverse. An embodiment contrary to this may be also adopted. The pattern of the ribs is not limited to the radial or concentrically circular pattern as mentioned above and other various patterns such as vortical pattern and grid pattern may be adopted.

Usually the body 1 has a uniform thickness (provided that the ribs are left out of consideration, the same hereinafter), but the body 1 may have different thicknesses in its individual portions. For instance, the body 1 is constructed so that it consists of three portions 1a, 1b and 1c which have different thicknesses from each other, as shown in Fig. 8 (plan view) and Fig. 9 (cross-sectional view). According to such an embodiment, it is possible to make the portions 1a, 1b and 1c having different thicknesses to bear different frequency bands, respectively. Therefore, the diaphragm of this embodiment is particularly preferable for full-range speaker. In Figs. 8 and 9, the body 1 is the thickest in the most inner portion 1a and thinner in the order of the portion 1b and the portion 1c in the direction towards the outer periphery of the body 1. Contrary to this, the body 1 may be the thickest in the most outer portion 1c and thinner in the order of the portion 1b and the portion 1a in the direction towards the inner periphery of the body 1, as shown in Fig. 10 (cross-sectional view). Steps are formed on the obverse of the body 1 by making the individual portions of the body 1 to have different thicknesses, as shown in Figs. 8 and 9. Contrary to this, the steps may be formed on the reverse of the body 1 and in that case, the obverse is flat. Further, the steps may be formed on both surfaces. Moreover, the thickness of the body 1 may be changed gradually so that such steps are not formed. When the individual portions of the body 1 are changed in thickness, concentrically circular ribs 5b may be provided on the boundary between the individual portions as shown in Fig. 10, whereby the interference among the portions 1a, 1b and 1c is reduced and the frequency bands born by the portions 1a, 1b and 1c are clearly separated from each other.

The characteristic of the diaphragm of the present invention is that it is particularly unnecessary to provide an edge. However, the diaphragm of the present invention may be provided with an edge 6, as shown in Fig. 9. The shape of the edge 6 is not particularly limited and various shapes such as circular arc, U-shape and V-shape in section as shown in Fig. 9, and bellows-like shape formed by joining a plurality of edges having the foregoing shapes can be adopted.

Fig. 11 is a plan view of other embodiment of the diaphragm of the present invention and Fig. 12 is a cross-sectional view of the embodiment. Numeral 7 is a flat plate-shaped body and numeral 8 is a fitting portion directly joined to the outer periphery of the body 7 without interposing an edge between them. The body 7 is attached to a driving cone at the fitting portion 8. In Figs. 11 and 12, the thickness of fitting portion 8 is greater than that of the body 7, but the thickness of the fitting portion 8 may be equal to or smaller than that of the body 7 when the body 7 per

se is thick.

The shape in plan of the flat plate-shaped body 7 is not limited to a circular shape as shown in Fig. 11 and other shapes such as elliptical shape and polygonal shapes may be adopted.

The flat plate-shaped body 7 is provided with ribs in the same manner as in the cone-shaped body 1. For instance, radial ribs 5a and a concentrically circular rib 5b may be provided, as shown in Fig. 13 (plan view), Fig. 14 (cross-sectional view taken on the line B-B of Fig. 13) and Fig. 15 (cross-sectional view taken on the line C-C of Fig. 13). Either the radial ribs 5a or the concentricall circular rib 5b may be omitted. The number, the pattern, etc. of the ribs 5a and 5b may be suitably decided in consideration of the strength and the caliber of the body 7 and the desired tone quality. The ribs 5a and 5b may be provided on the obverse of the body 7 or on the reverse of the body 7, or on both surfaces. According to another embodiment, the ribs 5a are provided on the obverse and the rib 5b on the reverse. An embodiment contrary to this may be also adopted. Various embodiments wherein the body 7 is provided with ribs are shown in Figs. 16 to 17, Figs. 18 to 19 and Figs. 20 to 22. The ribs in Fig. 16 (plan view) and Fig. 17 (cross-sectional view taken on the line D-D of Fig. 16) consist of only radial ribs 5a. The ribs in Fig. 18 (plan view) and Fig. 19 (cross-sectional view) consist of only concentrically circular ribs 5b. The ribs in Fig. 20 (plan view), Fig. 21 (plan view of the opposite side of Fig. 20) and Fig. 22 (cross-sectional view taken on the line E-E of Figs. 20 and 21) consist of radial ribs 5a provided on one surface of the body 7 and a concentrically circular ribs 5b provided on the opposite surface.

The flat plate-shaped body 7 may be constructed so that the body 7 has different thicknesses in its individual portions in the same manner as in the cone-shaped body 1. For instance, the body 7 is constructed so that it consists of three portions 7a, 7b and 7c which have different thicknesses from each other, as shown in Fig. 23 (plan view) and Fig. 24 (cross-sectional view). In that case, the body 7 may be the thinnest in the most inner portion 7a and thicker in the order of the portion 7b and the portion 7c in the direction towards the outer periphery of the body 7 as shown in Figs. 23 and 24. Contrary to this, the body 7 may be the thinnest in the most outer portion 7c and thicker in the order of the portion 7b and the portion 7a in the direction towards the center of the body 7. Steps are formed on the obverse of the body 7 by making the individual portions of the body 7 to have different thicknesses, as shown in Figs. 23 and 24. Contrary to this, the steps may be formed on the reverse of the body 7 and in that case, the obverse is flat. Further, the steps may be formed on both surfaces. Moreover, the thickness of the body 7 may be changed gradually so that such steps are not formed. When the individual portions of the body 7 are changed in thickness, concentrically circular ribs 5b may be provided on the boundary between the individual portions having the different thicknesses as shown in Figs. 23 and 24, so that the interference among the portions 7a, 7b and 7c is reduced and the frequency bands born by the portions 7a, 7b and 7c are clearly separated from each other.

The flat-plate shaped body 7 is also provided with an edge 6 in the same manner as in the cone-shaped body 1, for instance, as shown in Figs. 16 and 17.

Fig. 25 is a plan view of another embodiment of the diaphragm of the present invention and Fig. 26 is a cross-sectional view of the embodiment. Numeral 9 is a dome-shaped body.

The shape in plan of the dome-shaped body 9 is not limited to a circular shape as shown in Figs. 25 and 26 and other shapes such as elliptical shape and polygonal shapes may be adopted. In the same manner as in the cone-shaped body 1 and the flat plate-shaped body 7, the body 9 may be also provided with ribs, changed in thickness or provided with an edge.

In the diaphragm of the present invention, the thickness of the body is preferably about 0.3 mm. to about 2 mm., especially about 0.5 mm. to 1.5 mm. The edge may not be provided when the hardness of the body is not more than 30° in *A* hardness. However, it is desirable to provide the edge when the hardness of the body is more than 30° in *A* hardness.

The diaphragm of the present invention is obtained by molding and curing such a rubber composition as previously mentioned into such a shape as mentioned above. The manner may be the same as usual manners for producing moldings of cured rubbers. For example, a rubber composition is directly press-cured in a mold of a given configuration. As an alternative, an uncured sheet is prepared by calender molding or extrusion molding and then subjected to press curing. Injection molding is also possible. It is desirable that the ribs are formed in the mold at one time, but they may be shaped by cutting after curing. Further, the ribs may be made independently of the body of the diaphragm and bonded to the body with an appropriate adhesive or the like.

The diaphragm of the present invention will be explained by referring to Examples.

Examples 1 to 3

Diaphragms for loudspeaker were produced using the rubber compositions shown in Table 1. Example 1, Example 2 and Example 3 were directed to the productions of a diaphragm for woofer, a diaphragm for squawker and a diaphragm for tweeter, respectively.

Table 1
Rubber composition (in parts)

Components	Examples		
	1	2	3
Norsorex 150 NA (Note 1)	250	–	–
Nipol SBR 1712 (Note 2)	–	137.5	–
Natural rubber	–	–	100
DOG factice F 10 (Note 3)	270	320	30
Sunthene 255 (Note 4)	700	22	–
FEF carbon	25	65	80
Zinc Oxide	5	5	5
Stearic acid	1	1	1
Antioxidant DDA (Note 5)	2	2	2
Suntight S (Note 6)	2	2	2
Sulfur	2	2	2
Sunceller CZ (Note 7)	12	3	2

Note 1: Polynorbornene (Norsorex, average molecular weight of not less than 2×10^6) extended with 150 parts of naphthenic oil per 100 parts of polynorbornene, sold by Nippon Zeon Co., Ltd. (Norsorex: registered trademark)

Note 2: Styrene-butadiene rubber extended with 37.5 parts of a high aromatic oil per 100 parts of the rubber, made by Nippon Zeon Co., Ltd.

Note 3: Amber sulfur factice made by D.O.G. Deutsche Oelfabrick Ges. f. Chem. Erz. mbh & Co.

Note 4: Naphthenic oil made by Japan Sunoil Co., Ltd.

Note 5: Diphenylamine antioxidant made by Bayer A.G.

Note 6: Microcrystalline wax made by Seiko Kagaku Kabushiki Kaisha

Note 7: N-cyclohexyl-2-benzothiazyl sulfenamide made by Sanshin Kagaku Kabushiki Kaisha

The rubber component was first scoured at about 60°C. and then kneaded with other components by means of a Banbury mixer and further a roll and sheeted out to give a sheet of about 2 mm. to about 3 mm. thick. A disk was cut out from the sheet and cured by a press machine with a give mold under a pressure of 150 kg./cm^2 at 155°C. for 20 minutes to give respective diaphragms having the following shapes:

Diaphragm of Example 1 (woofer)
Shape: Figs. 13 to 15
Overall diameter of the diaphragm: 236 mm.
Thickness of the body 7: 0.8 mm.
Radial ribs 5a:
Number: 16
Length: 42 mm.
Width: 2 mm.
Height: 0.8 mm.
Concentrically circular rib 5b:
Number: 1
Width: 6 mm.
Height: 0.8 mm.
Fitting portion 8:
Width: 10 mm.
Thickness: 1.6 mm.

Diaphragm of Example 2 (squawker)
Shape: Figs. 13 to 15
Overall diameter of the diaphragm: 100 mm.
Thickness of the body 7: 0.7 mm.
Radial ribs 5a:
Number: 16
Length: 18 mm.
Width: 2 mm.
Height: 0.7 mm.
Concentically circular rib 5b:
Number: 1
Width: 3 mm.
Height: 0.7 mm.
Fitting portion 8:
Width: 5 mm.
Thickness: 1.4 mm.

Diaphragm of Example 3 (tweeter)
Shape: Figs. 16 to 17
Overall diameter of the diaphragm: 80 mm.
Body 7:
Diameter (the diameter of the diaphragm except the edge 6 and fitting portion 8): 50 mm.
Thickness: 0.7 mm.
Radial ribs 5a:
Number: 12
Length: 12 mm.
Width: 1.5 mm.
Height: 0.7 mm.
Edge 6:
Shape: U-shape in section
Thickness: 0.7 mm.
Fitting portion 8:
Width: 5 mm.
Thickness: 1.4 mm.

Test pieces were cut out from the obtained diaphragms and various physical properties were measured on the test pieces. The results thereof are shown in Table 2. Measurements of impact resilience, tensile strength and elongation indicated in Table 2 were conducted according to JIS K 6301-1969.

Table 2

Physical properties	Examples		
	1	2	3
A hardness (degree)	7	30	70
Impact resilience (%)	73	57	46
Tensile strength (kg./cm^2.)	20	25	122
Elongation (%)	372	245	330
Specific gravity	1.004	1.057	1.178

The diaphragms obtained in Examples 1, 2 and 3 were attached to speakers put on the market instead of the flat plate-shaped diaphragms thereof to give a woofer, a squawker and a tweeter, respectively. The obtained speakers were set in an enclosure put on the market to give a three-way speaker system. In that case, no absorbing material was employed. Employing the speaker system, a listening test was carried out. For comparison, the same listening test was also carried out on a three-way speaker system put on the market which consisted of a woofer having a cone-shaped paper diaphragm with a caliber of 30 cm., a squawker having a cone-shaped paper diaphragm with a caliber of 15 cm. and a tweeter having a cone-shaped paper diaphragm with a caliber of 5 cm.

(1) Play-back equipment

Pre-main amplifier: AU-D907 (made by Sansui Electric Co., Ltd.)

Player: DP-40F (made by Nippon Columbia Co., Ltd.)

Cartridge: V-15 type 3 (made by Shure Brothers, Inc.)

(2) Location

About 40-tatami mat room (equipped with an air conditioner and a ventilator)

Floor: Vinyl-tiled (with mortared underlying layer)
Ceiling: Flat noninflammable material (no sound-absorption opening)
Inner walls: Plywood

(3) Test method

A panel of 4 trained listeners was instructed to hear the following record and score them on the following parameters.

Test record
Title of record: Flamenco Fever (Miller and Kreisel Sounds Corp. in U.S.A.)
Performer: The Philharmonia Hungarica
Program: Llorona (traditional)

Parameters and standards for evaluation

(a) Weightiness of bass sounds
Excellent: The weightiness was very rich.
Good: The weightiness was rich.
Ordinary: The weightiness was poor.

(b) Reverberation
Excellent: There was no reverberation.
Good: There was a little reverberation.
Ordinary: There was a considerable reverberation.

(c) Distortion of bass sounds
Excellent: There was no distortion.
Good: There was a little distortion.
Ordinary: There was a considerable distortion.

(d) Impressions of presence
Excellent: The presence is very rich.
Good: The presence is rich.
Ordinary: The presence is poor.

The results of the listening test were shown in Table 3. The evaluations of 4 listeners were entirely the same with each other.

Table 3

Parameters	Speaker system	
	The invention	Comparative
Weightiness of bass sounds	Excellent	Ordinary
Reverberation	Excellent	Ordinary
Distortion of bass sounds	Excellent	Ordinary
Presence	Excellent	Ordinary

As is clear from Table 3, the diaphragms of the present invention gave excellent results on all parameters, as compared with the conventional paper diaphragms. A noticeable point was that there were reproduced delicate source sounds, for instance, such sounds as made when the thin board of the floor was broken by taps, such sounds as made when the palm of a hand which had been touched on the skin of a drum was separated from the skin and such sounds as made when the vocal chords trembled. Such delicate sounds could not be reproduced absolutely by conventional speakers and could be heard only in live performance. For the first time, it has been made possible to reproduce such delicate sounds as mentioned above by a speaker employing the diaphragm of the present invention.

Examples 4 to 6

Employing rubber compositions shown in Table 4, diaphragms for loudspeaker were produced in the same manner as in Examples 1 to 3. Examples 4 and 5 were directed to the production of a diaphragm for woofer. The shapes of the diaphragms of Examples 4 and 5 were the same as that of the diaphragm of Example 1. Example 6 was directed to the production of a diaphragm for squawker. The shape of the diaphragm of Example 6 was the same as that of the diaphragm of Example 2 except that an edge 6 was provided.

The physical properties of the diaphragms obtained in Examples 4 to 6 are shown in Table 5.

Table 4
Rubber composition (in parts)

Components	Examples		
	4	5	6
Norsorex 150 NA	–	250	–
Nipol SBR 1712	137.5	–	–
Nipol IR 2200 (Note)	–	–	100
DOG factice F 10	270	230	220
Sunthene 255	–	400	22
Dioctyl phthalate	–	50	–
FEF carbon	–	50	85
SRF carbon	40	–	–
MT carbon	45	–	–
Zinc oxide	5	5	5
Stearic acid	1	1	1
Antioxidant DDA	2	2	2
Suntight S	2	1	2
Sulfur	2	2.5	2
Sunceller CZ	4	8	4

Note: Isoprene rubber made by Nippon Zeon Co., Ltd.

Table 5

Ex. No.	Hardness (degree)			Impact resilience (%)	Tensile strength (kg./cm^2.)	Elongation (%)	Specific gravity
	A hardness	*C* hardness	*F* hardness				
4	18	–	–	60	21	364	1.016
5	–	11	73	63	6.5	387	0.977
6	50	–	–	41	26	210	1.244

Employing the respective diaphragms obtained in Examples 4 and 5, two kinds of woofers were produced. The respective woofers were employed instead of the woofer employing the diaphragm of Example 1 in the previously obtained three-way speaker system. The resulting speaker systems gave the same excellent bass sounds as those obtained by the previously obtained three-way speaker system.

Employing the diaphragm obtained in Example 6, a squawker was produced and it was employed instead of the squawker employing the diaphragm of Example 2 in the previously obtained three-way speaker system. The resulting speaker system gave the same excellent sounds in the mean as those obtained by the previously obtained three-way speaker system.

CLAIMS

1. A diaphragm for loudspeaker comprising a cured molding of a rubber.

2. The diaphragm of Claim 1, wherein the cured molding has a hardness within the range of not more than 80° as measured with an A-type rubber hardness tester and not less than 15° as measured with an F-type rubber hardness tester and an impact resilience of not less than 40 %.

3. The diaphragm of Claim 2, wherein the hardness is not more than 30° as measured with the A-type rubber hardness tester.

4. The diaphragm of Claim 3, wherein the hardness is not more than 20° as measured with the A-type rubber hardness tester and not less than 30° as measured with the F-type rubber hardness tester and the impact resilience is not less than 50 %.

5. The diaphragm of any of Claims 3 and 4, wherein the cured molding is a cured molding of a rubber compostion comprising (A) 100 parts by weight of a rubber component, (B) 5 to 2,000 parts by weight of a factice and (C) 20 to 2,000 parts by weight of a softening agent.

6. The diaphragm of Claim 5, wherein the amount of the component (B) is from 100 to 1,500 parts by weight and the amount of the component (C) is from 200 to 1,500 parts by weight.

7. The diaphragm of Claim 5, wherein the component (A) comprises polynorbornene predominantly.

8. The diaphragm of Claim 1, wherein the body of the diaphragm is cone-shaped.

9. The diaphragm of Claim 1, wherein the body of the diaphragm is flat plate-shaped.

10. The diaphragm of Claim 1, wherein the body of the diaphragm is dome-shaped.

11. The diaphragm of any of Claims 8, 9 and 10, wherein the body of the diaphragm is provided with no edge at the periphery thereof.

12. The diaphragm of any of Claims 8, 9 and 10, wherein the body of the diaphragm is provided with ribs.

13. The diaphragm of any of Claims 8, 9 and 10, wherein the body of the diaphragm comprises portions having different thicknesses from each other.

14. A diaphragm for loudspeaker substantially as described herein with reference to the accompanying drawings.

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